OWNER'S MAINTENANCE GUIDE

for

Stormwater BMPs Constructed in the City of Durham

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INTRODUCTION

The contribution of stormwater runoff to the problems of surface water quality has received increasing attention and regulation in recent years. Depending on the land use over which stormwater flows, the impacts of polluted stormwater on the environment can and will vary. The pollutants of primary concern are sediments, nutrients (such as nitrogen and phosphorous), bacteria, toxics (such as heavy metals), and hydrocarbons. Because stormwater runoff is, more or less, generated when and wherever rainfall hits the ground, contaminated runoff enters the surface water environment in multiple source locations. This diffuse manner in which stormwater pollutants enter the environment has led to the term "Non-Point Source," or NPS, pollution. This term is intended to distinguish such overland sources from point sources, such as discharges from a waste water treatment plant or from an industrial manufacturing facility.

The management of all water pollution sources, both point and non-point sources, is a written goal of the 1987 amendments to the Federal Clean Water Act. An important source of NPS pollution is stormwater runoff generated by urbanized and developing areas. NPS pollution can degrade water quality in all types of waters from nutrient sensitive waters in a water supply overlay to the small creek that runs through your neighbor's back yard to the "recreational" lake at the community park down the street. Stormwater Best Management Practices (BMPs) are implemented as a way of treating or reducing the amount of pollutants in stormwater runoff. The wet pond or constructed wetland in your neighborhood or the open sand filter device in the parking lot of the gas station you frequent are examples of just some of the many types of BMPs used in the City of Durham and throughout the United States.

The proper design and construction of an engineered BMP is essential to its ability to adequately remove pollutants from stormwater runoff. Equally important is the proper operation and upkeep of such a facility. Without proper maintenance, a BMP will not function as it is intended and, in some instances, may cause a host of problems from dangers to the public to nuisance odors to reduced property values. The purposes of this guide are three-fold:

1. To acquaint BMP owners with the essential functional elements of the BMP on their property or in their neighborhood;
2. To help BMP owners identify the maintenance requirements for such a BMP; and
3. To help BMP owners establish and implement an effective BMP operation and maintenance program for the BMP.

Each Section of this guide will address the functional elements and typical maintenance requirements for each type of structural BMP used in the City of Durham. It should be noted that this guide is intended to provide a general overview of the common maintenance items that will or may arise in the course of operating a particular type of BMP. While this guide can be used as a basis for the preparation of a BMP specific operation and maintenance plan, it should not be confused with an actual operation and maintenance plan for such a BMP. Again, this guide is for general purposes only. If site specific guidance for a particular BMP is desired or required, it is recommended that the services of a Professional Engineer or, if appropriate, a Registered Landscape Architect, be retained to prepare an operation and maintenance plan specific for that BMP.

SECTION 1

STORMWATER PONDS

Dry Ponds, Wet Ponds, and Stormwater Wetlands

FUNCTIONAL ELEMENTS

Definitions of Device Types

Dry Pond: A dry pond is a constructed stormwater device that temporarily stores incoming stormwater, trapping some pollutants, and, through its detention capacity, reduces the frequency and severity of downstream flooding and erosion.

Wet Pond: A wet pond is a constructed stormwater device that includes a permanent pool of water to remove pollutants from stormwater. Sometimes, like with dry ponds, additional capacity is provided to reduce downstream flooding and erosion.

Stormwater Wetland: A stormwater wetland is a constructed stormwater device that emulates the functions of a natural wetland area and uses physical, chemical, and biological processes to treat stormwater. The impoundment area for such a device is designed to be inundated or saturated periodically by groundwater and stormwater runoff and will support vegetation conducive to such conditions.

Glossary of Primary Elements

Dam: An earthen embankment or wall (or some combination of the two) that creates an intermittent or permanent water impoundment.

Dam Abutment: The point where the top of the dam ties-in to existing ground. The left abutment is the point where the top of the dam ties-in to existing ground to the left of the riser structure (when facing away from [e.g, downstream of] the riser structure). The right abutment is the point where the top of the dam ties-in to existing ground to the right of the riser structure.

Dam Groin: The point where the constructed fill in the dam ties-in to existing ground between the abutment and the toe of a dam. Typically, there is a left groin upstream face, a right groin upstream face, a left groin downstream face, and a right groin downstream face.

Dam Toe: The lowest point in the dam where the constructed fill in the dam ties-in to existing ground. The upstream toe is, typically, the zone near the riser structure, and the downstream toe is, typically, the zone near the outfall area.

Emergency Spillway: A supplemental channel or structure that routes larger emergency storm flows around or through an earthen embankment dam. In the instance of a concrete dam, the emergency spillway may be a lower-level weir intended to provide release of emergency flows to protect the dam during large storm events. The intent of an emergency spillway is to lower the chances of dam overtopping during a flood larger than the design capacity of the facility.

Forebay or Sediment Basin: A depression (sometimes lined with rock) located where a pipe or swale enters a pond. It is intended to capture particulate pollutants, such as small stones, sand, and heavy sediment, by slowing the water velocity such that particulates are able to settle out in a relatively confined area.

Impoundment Area: The area upstream of a dam that stores water intermittently or permanently. This area includes the forebay/s or sediment basin/s.

Inlet: A pipe or channel that discharges collected stormwater into the impoundment area of a stormwater pond.

Outfall: The point where water leaves a pond and enters the downstream drainage system. This point is usually at the downstream discharge point of the principal spillway pipe.

Principal Spillway Pipe: The principal pipe that coveys water from the riser structure to the outfall.

Riser: This structure is located in the impoundment area of a pond, in the vicinity of the upstream face of the dam, and is the principal water release structure in a pond. This is the structure that regulates the rate at which stormwater exits the pond and is usually attached to the upstream end of the principal spillway pipe for the facility. This structure is normally a circular or square concrete structure rising up above the ground and the permanent pool of water (if applicable). It usually has a trashrack on top, which is intended to prevent trash and large debris from entering the structure.

MAINTENANCE REQUIREMENTS

Erosion and Sediment Control Requirements

In accordance with City and County of Durham requirements, erosion and sediment controls are required anytime a land disturbing activity is proposed. If more than 12,000 SF of land disturbance is proposed, an erosion and sediment control permit will be required from the County of Durham prior to the commencing any such land disturbing work; if more than one acre of land disturbance is proposed, an erosion and sediment control plan must be submitted to and approved by the County of Durham prior to the commencing of any such land disturbing work. Questions regarding erosion and sediment control requirements should be directed to Durham County Erosion and Sediment Control at 919/560-0739.

Dam Embankment/Emergency Spillway Maintenance

<u>Turf Maintenance</u>

- Any bare areas on the dam should be raked vigorously and covered with a two-inch layer of topsoil. These areas should then be seeded with a turf grass seed mix and mulched with straw. Depending on the time of year and rainfall amounts, additional watering of the seeded areas may be required. When a potable water source is not readily available (or even if it is) and the pond contains a permanent pool of water, it is recommended that a sump pump watering system be implemented, where water is drawn from the pond to irrigate the newly seeded areas. During extreme droughts, it may be necessary to contract out the trucking in of reclaimed wastewater from a nearby wastewater treatment facility.
- Depending upon rainfall amounts, the grass on the dam should be mowed at least three- to four-times during both growing seasons (e.g., the spring and fall) and at least once during the summer. The grass should never exceed a height of 18" and, when cut, should be cut to a height of approximately six-inches. If a shorter cut height is desired, more frequent mowing will be required (10 to 15 times per year) to avoid cutting too much of the plant with each mowing cycle. Special care against "scalping" should be exercised along all sloped areas and in areas where terrain grades change abruptly.
- Grass seed should be applied during the beginning months of both growing seasons.
- Lime should be applied any time from March through November. Liming rates should be based on soil test results. It is recommended that the soils on the dam be tested on a biennial basis. Soil test kits can be obtained from the North Carolina Cooperative Extension Service, which is located at 721 Foster Street, Durham, NC (919/560-0525). The soil tests are performed by the NC State University Soil Testing Lab and are offered free of charge. Test results are provided in the mail.
- Fertilizer, if its use is approved, should be applied sparingly in accordance with soil test recommendations. Typically, fertilizer should be applied in October or

November. In most instances, once a turf grass has been established on a dam, the application of fertilizer should no longer be necessary and, in fact, should not be used without specific approval of the Stormwater Services Division.

<u>Trees, Shrubs, etc.</u>

An earthen dam, and all areas within 7- to 10-ft of the toe, groin, and abutment areas of the dam, should be kept free of trees, shrubs, ornamental plantings, and scrub brush. Over time, tree roots can become quite extensive, extending far below normal pool ponding levels. These roots can provide paths for seepage and may even weaken the compacted soil structure of the dam. Large trees can uproot, leaving voids and depressions, which may weaken the dam or lead to erosion. Additionally, small trees, shrubs, brush, and other woody vegetation may prevent observation and inspection of dam surfaces and may provide a haven for burrowing animals such as groundhogs and muskrats.

Existing ornamental trees, shrubs, and other landscaping can be transplanted from the dam to other more appropriate locations. The fall is the best time to transplant these items. All other trees and dense vegetation should be cleared from the dam as soon as practicable. The stumps of small trees (e.g., four-inch caliper and below) should be grubbed-out or ground-down to at least six-inches below the ground surface. Larger trees should be removed and all roots greater than one-inch in diameter grubbed out. For large, stand-alone trees, a suggested alternative to the grubbing operation above is the careful removal of roots through attaching a chain to individual roots and systematically pulling them out with machinery. The voids left should be "mud-packed" (e.g., filled with a soil-cement slurry [one-part cement, nine-parts sand, and enough water to enable the slurry to flow] and then covered with topsoil). It should be noted that the removal of large trees may require that a pond be drained first. To ensure the structural and functional integrity of the dam, any tree removal operations involving the removal of trees greater than 12" in diameter should be performed under the guidance of a registered Professional Engineer with expertise in the design, construction, and maintenance of dams. All disturbed areas should be covered with topsoil, seeded, and mulched.

<u>Piping Failure</u>

Piping is the progressive loss of soil from an earth dam (usually around and/or into the principal spillway pipe) resulting from concentrated seepage of water through the dam. The repair of a piping condition can be fairly complex, as well as costly. Proper repair <u>may</u> include complete (or partial) replacement of the outlet works, partial reconstruction of the dam, and installation of seepage control facilities. Wet ponds, where piping has occurred, should be drained (until repaired) to maintain public safety, protect downstream property, and protect the downstream environment. Consultation with a registered Professional Engineer is recommended.

<u>Wet Areas on the Downstream Face or at or beyond the Downstream Toe</u>

Wet areas <u>may</u> be indicative of seepage through the dam. These areas should be monitored periodically for any changes in the nature of the wet areas and/or the development of slope failure or slippage areas. If such a condition results, consultation with a registered Professional Engineer is recommended. Tip: One of the best times to determine the presence of an active seep is during the dead of winter (e.g., when surficial water is frozen). In addition, the presence of wetland type vegetation at or near the toe of a dam may be an indicator of a seepage problem as well.

<u>Hydraulic (Overtopping) Failure</u>

Erosion head-cuts and debris on the downstream face and/or at the downstream toe of a dam are evidence that the dam may have overtopped. Eroded areas should be repaired immediately and the causes of the overtopping investigated. Overtopping events are usually the result of very intense rain events, significant loss of impoundment volume (above normal pool), and/or an inadequate or blocked emergency spillway. Wet ponds and wetlands, where hydraulic failure has occurred, should be drained until repaired. Consultation with a registered Professional Engineer is recommended.

<u>Fill Condition Emergency Spillway</u>

The best assurance against dam overtopping is an adequate emergency spillway. Severe erosion of a dam embankment, which could lead to dam failure, can occur if a dam does overtop. This is the primary reason dams should be protected against overtopping. An emergency spillway constructed in fill cannot protect a dam adequately as it will be subject to a hydraulic failure potential similar to that of an overtopped dam, only more frequently. An owner of a dam with a fill condition emergency spillway should consult a registered Professional Engineer regarding the spillway.

<u>Absence of an Emergency Spillway or an Adequately Sized/Constructed Emergency Spillway</u>

Again, the best assurance against dam overtopping is an adequate emergency spillway. An owner of a dam without an emergency spillway or without an adequate emergency spillway should consult a registered Professional Engineer regarding the provision of an adequate spillway.

<u>Washed-out/Severely Eroded Emergency Spillway</u>

An owner of a dam with an emergency spillway in hydraulic failure should consult a registered Professional Engineer regarding an appropriate method of repair and revetment of the spillway.

<u>Homes or Other Habitable Structures Located in the Discharge Zone of the Emergency Spillway</u>

An owner of a dam with homes or other structures located in the discharge zone of the emergency spillway should consult a registered Professional Engineer to assess the condition.

<u>Cloudy/Muddy Foundation/Toe Drain Discharges</u>

Foundation or toe drain discharges should be clear. If they are cloudy or muddy, the filter for the internal drainage system (i.e., diaphragm, drainage blanket, chimney drain, toe drain, etc.) may have failed resulting in the piping of embankment material through the dam and into the drainage mechanism. The drains should be flushed and the material discharge tested for a determination as to the nature of the material. Repair of the filter and drainage systems may be necessary. The presence of iron filings in the discharge is, typically, not a concern. Consultation with a registered Professional Engineer is recommended.

Surface Erosion Repair

The greatest threat to an earthen dam is erosion. Erosion can result from surface run-off, wave action, rapid changes in pool levels, or pedestrian, vehicular, or animal traffic. All eroded areas should be repaired as soon as practicable. Special attention should be directed toward mitigating the source(s) of erosion by employing one or more of the following maintenance activities:

- Maintaining a healthy stand of grass.
- Armoring the upstream face of the dam (from 3-ft below to 3-ft above the normal pool) with riprap (or an approved equivalent) to reduce wave erosion (large wet ponds only).
- Providing paved trails for pedestrian access.
- Providing convenient access points and travel surfaces for maintenance vehicles.

Depressed Areas

Depressed areas may be indicative of a problem. A depressed area can often be the result of poor final grading at original construction or subsequent maintenance activities (i.e., tree removal, etc.). If the cause is indeterminate based on a lack of institutional history regarding the dam, monitoring of the depressed area/s is recommended. Control points could be established in these areas and then surveyed periodically to chart any additional settlement or movement. If changes are noted over time, consultation with a registered Professional Engineer is recommended.

Slope Failure

Areas of slope slippage may be indicative of a concentrated seep exiting through the downstream face of the dam or may be indicative of slope instability on the upstream face of the dam (usually resulting from rapid draw-down conditions). Both types of slope failure can seriously threaten the integrity of a dam. Consultation with a registered Professional Engineer is recommended.

Desiccation (Shrinkage) Cracks

During dry (desiccated) seasons, the clay in dam embankments may shrink, resulting in the “allegation,” or cracking of the embankment surface. Though typically not a significant threat, shrinkage cracks can worsen progressively through rainfall infiltration and multiple freeze-thaw cycles. Close monitoring should be provided. Cracks wider than one-inch and/or deeper than one-foot should be mud-packed, as described previously.

Fracturing

Fractures are defined as cracks wider than one-inch and deeper than three-feet. Typically, fractures will have distinctly defined directions (i.e., parallel to the axis of the dam, perpendicular to the axis of the dam, etc.). In addition, the edges of the crack will more than likely be offset vertically, giving a “fault” like appearance. Such a condition may be indicative of differential settlement in the dam or foundation support problems. Fractures can seriously threaten the integrity of a dam. Consultation with a registered Professional Engineer is recommended.

Rodents

The three rodents most destructive to an earth dam are the groundhog, the muskrat, and the beaver. These animals are attracted to the environment and habitat provided by a dam and reservoir. Beavers may attempt to plug up the principal spillway in order to raise the elevation of the reservoir water surface (or create one in a "dry pond"). The burrowing habits of the groundhog and the muskrat may threaten the integrity of an earth-filled structure. Groundhogs typically burrow into a dam on the downstream face. The burrow may have many tunnels and chambers, and will always have at least two, if not several, entrances. Muskrat dens are constructed in the banks of lakes and streams. These burrows start from six to eight inches below the normal pool (sunny day water surface) and then tunnel upward toward dry ground. These burrows may provide a path for water to flow through the dam, which can weaken the dam. It becomes even more hazardous when a muskrat den on the upstream side connects with a groundhog den on the downstream side, resulting in an unlined conduit through the dam. It should be noted that a well-mowed dam discourages rodent infestation and habitation. Professional trapping of these rodents may be necessary. Once the rodents have been removed, any burrow holes should be "mud-packed," as described previously.

Riser Structure Maintenance

Blockages

All trash and debris blocking the entry or passage of storm flows into or through the riser should be removed.

Insufficient Debris Management

Flat top trashracks are often subject to blockages from floating/settling debris. A peak-roofed trashrack is far preferable, as it will grant a larger factor of safety against debris blockage. Details for such racks can be obtained from the Stormwater Services Division.

Accessibility

Accessibility to the riser structure is necessary for maintenance personnel. A lockable access hatch through the top of the structure (or trashrack) and steps (or a ladder) up the outside and then down the inside of the structure are recommended.

Structural Deterioration

Depending on the severity of the deterioration, the riser structure may need to be replaced. Undermined areas should be filled with a flowable fill (slurry) and then monitored for additional undermining.

If the riser has settled, monitoring of the condition is recommended. Vertical and horizontal control points could be established on the riser and then surveyed periodically to document any changes.

If the overall integrity of the structure is reasonably sound, the following repairs should be considered:

- Cracks should be sealed with an epoxy low-shrink grout.
- Spalled areas should be repaired with a multi-component (epoxy/Portland cement) bonding agent, such as CORR-BOND, and then painted. The paint should include a water-proofing additive.
- Rusted areas (if reparable) should be scraped, cleaned, primed, painted with two coats of rust-resistant paint, and, if appropriate, coated with a bituminous sealant.

<u>Low-Level Release Devices</u>

Nearly all low-level release devices (i.e., plug valves, gate valves, sluice gates, etc.) will, over time, begin to leak. Minor leaks are not a significant concern. If, however, a release is leaking to such a point that the normal pool water surface elevation cannot be maintained, the leaking condition should be addressed. If the low-level release is leaking, it may be that the release is not completely closed, that it is damaged, or that the sealant surrounding the penetration of the release has deteriorated. A thorough inspection of the release should be performed to ascertain the cause(s) of the leak. If the facility is damaged, the company that manufactured the device should be contacted. If the seal around the device has broken away, the old seal should be removed, and a low-shrink grout should be used to reseal the penetration.

It is recommended that all low-level release facilities be exercised (e.g., opened a few inches, allowed to run for about five or ten minutes, and then closed) at least once a year. Prior to opening the device, an attempt should be made to clear away any debris that has collected in the area around the gate or valve inlet. In addition, it is strongly recommended that any grease fittings or ports be greased immediately preceding and following the opening of the device.

<u>Redundant Gates/Valves (for Lakes with Normal Pool Depths Greater than 12-ft at the Riser Structure</u>

To allow greater drawdown flexibility, a secondary gate or valve is recommended. This device should be set at an elevation that will allow for the complete draining of the top 4- to 6-ft of the normal pool volume. Such a device will enable a lake owner to clean out the forebays for and/or the upper reaches of the lake more easily. In addition, such a device will provide for the ability to lower the lake in anticipation of very large rain events (e.g., emergency spillway activating events) or, when necessary, to lower the phreatic surface (the zone of saturation) in the dam and, thereby, reduce the hydrostatic pressure on the downstream toe of the dam.

Principal Spillway Pipe (PSP) Maintenance

<u>Blocked PSP</u>

A blocked PSP should be opened up as soon as practicable. Sometimes, such an operation will require the removal of sediment from the outfall area. A blocked PSP may be an indication of inadequate debris management at the riser structure. Details for debris management devices can be obtained from the Stormwater Services Division.

Deteriorated PSP Connection to the Riser Structure

If the connection of the PSP to the riser has deteriorated, the old connection parging should be removed, the joint cleaned, wetted, and resealed with an epoxy low-shrink grout.

Leaking Joints

All PSPs without gasketted joints will leak to a certain degree, especially in the vicinity of the first three to four sections of pipe downstream of the riser structure. All joints in pipes with diameters of at least 3-ft should be visually inspected at least once a year for signs of infiltration of embankment material (i.e., soil stainage plumes at the joints, etc.). It is recommended that all concrete pipe joints be sealed from the inside with an epoxy low-shrink grout, and then monitored periodically for additional signs of leakage and embankment infiltration. Metal pipe joints should be cleaned, and a waterproofing sealant should be pressure injected into the open gap(s) in the pipe joint. If significant problems persist, consultation with a registered Professional Engineer is recommended.

Structural Integrity

If the integrity of the PSP is questionable (e.g., there are signs of excessive pipe settlement or misalignment or there are signs of separated, crushed, rusted-out, or undermined sections of pipe), complete or partial replacement of the pipe may be necessary. In such instances, consultation with a registered Professional Engineer is recommended.

Outfall Structure Maintenance

Slight (e.g., 3- to 4-inch) Separations

An outfall structure that has separated from the main PSP should be reconnected and sealed with an epoxy low-shrink grout.

Severe Undermining or More Severe Separations

If the outfall structure has been severely undermined or has been dislodged from the PSP, the structure should be temporarily removed, the subbase reconstructed, and the structure reset. To preclude subsequent undermining, a concrete curtain wall should be installed to support the downstream end of the structure. This curtain wall should extend a minimum of six-inches below the bottom of any adjacent riprap (e.g., rock). The placement of additional (or larger) riprap in the outfall area may be necessary.

Safety Railing

Safety railing, with a low climability potential, or fencing at all drop structures is recommended. Typically, such railing or fencing should be installed across the top of the riser or endwall and down each wing (if present) whenever the drop from the top of the structure to the adjacent ground surface or outfall area is 3-ft or greater.

Outfall Area Maintenance

Blockages

A blocked outfall channel should be opened up as soon as practicable, especially if the channel is backing a significant amount of water up inside the PSP. Typically, outfall channels should be cleared of trees for a distance, downstream from the outfall structure, of at least 5 times the diameter of the PSP. For example, the clearing area for a 36" (three-foot) diameter PSP would be 15-feet long. Note: Established vegetation and trees on the stream banks should be left in place. The "clearing" should be limited to the removal of dead and fallen trees, trash, excessive sediment, and anything in the flow-line of the channel that significantly prevents water from exiting the pond facility.

Erosion

Eroded outfall channels should be repaired as soon as practicable with additional riprap armoring or other permanent lining material.

Impoundment Area Maintenance

Sedimentation of Forebays and Sediment Basins

Once significant portions of the "planned" sedimentation areas have filled-in (approximately 25-30% by volume or once the level of sediment reaches an elevation of less than one-foot below the normal pool), these areas should be cleaned/dredged. Typically, these areas will need to be cleaned out once every 3- to 5-years.

> **Note 1:** The North Carolina Department of Environment and Natural Resources, Division of Water Quality (919/733-7015) or Division of Waste Management/Hazardous Waste Services (919/508-8400), should be contacted regarding the proper testing and disposal of dredged material if it is to be hauled off-site.
>
> **Note 2:** Given the clay soils in Durham, most dredging operations in ponds with a permanent pool of water will, in all likelihood, result in a clay turbidity condition during and then for weeks following such operations. To mitigate this condition, immediately following the completion of dredging operations, agricultural lime should be spread over the entire water surface to facilitate the settling out of excess clay particles. Suggested liming rates and distribution methodologies are discussed in succeeding sections of this document.

Forebay Berms

Sometimes, due to fluctuations in pool depths, incoming flows may erode a portion of one of the forebay berms. An eroded forebay berm should be repaired as soon as practicable. It is recommended that the repaired portion be rebuilt to a height approximately 18- to 24-inches below the original height of the berm and that the rebuilt portion be armored with a 12- to 18-inch deep blanket of riprap (Note: The riprap should be installed to the downstream toe of the forebay berm slope and should be underlain with vinyl filter fabric). This reconstructed berm section will provide an armored spillway over the berm, which should mitigate future erosion problems.

Shoreline Erosion and Nuisance Water Fowl Mitigation

Eroded shorelines should be repaired as soon as practicable. Often, by allowing (or encouraging) a 10- to 30-foot wide riparian buffer to grow up around the shoreline (exclusive of the dam embankment), the erosive condition may subside. If such erosive conditions persist, however, more aggressive measures may be required. To address persistent erosive conditions, “soft measures” (i.e., biologs, reed clumps, live-staking, etc.) are encouraged. However, in areas of heavy pedestrian traffic (i.e., heavily fished areas, etc.) riprap stabilization may be more successful. Specific fishing areas could be installed and cordoned off with split rail fencing to limit fishing activities to those areas.

The provision of a riparian buffer may also mitigate pollutants from running off adjacent properties into the pond and may discourage Canada geese activity. It should also be noted that the installation of small fencing (e.g., 2-ft tall, reinforced wire fencing) around the impoundment water surface may also help to discourage Canada geese from taking up residence in the pond. Such fencing, which comes in 25-ft rolls, as well as the 3-ft tall metal support stakes and the wire ties, can be purchased from hardware stores, such as Home Depot or Lowes, at a cost of around $1.50/LF.

Inlets

Inlets to a pond should be kept open and in good working condition. All eroded areas should be repaired.

Large Debris

Large debris within the ponding area should be removed unless it is felt that the debris (i.e., downed tree, etc.) may contribute to an increase in habitat structure and will not affect adversely the operation or maintenance of the pond.

Sedimentation/Poor Health

If sedimentation is becoming a problem (i.e., silt bars have begun to form in the upstream ends of the impoundment area, etc.), clean-out of the pond may be necessary. It is suggested that soundings in these areas be taken to determine sedimentation quantities. Consultation with a registered Professional Engineer regarding sediment removal operations and the efficacy of a future forebay may be prudent. To maintain a wet pond environment, as opposed to allowing the pond to transition into more of a wetland environment, wet ponds typically require major dredging in the upper reaches and cove areas once every ten- to 15-years. Ponds with forebays require clean-out far less frequently. The forebays, however, may require clean-out as often as every three- to five-years. When considering a dredging operation, the issue of where to decant dredged material should be considered thoroughly.

If a wet pond is showing signs of poor health (i.e., nutrient overload, excess/invasive aquatic vegetation, algae, severe turbidity, fish kills, etc.), consultation with an ecologist and a registered Professional Engineer is recommended.

Water Quality Parameters

(Primary Source: *Virginia Pond Aquaculture: Water Quality Summary*, B.L. Nerie, PhD., Extension Specialist, Aquaculture)

In general, the following water quality parameters should be considered and evaluated periodically:

- **Light**: Almost all energy driving a pond system is from sunlight. Microscopic green plants (algae or phytoplankton) in pond water use light energy to drive photosynthetic activity. Photosynthesis is a process by which oxygen is released into a pond for use in respiration by fish and other pond organisms. Several cloudy days in a row can limit the amount of oxygen added to the water. The major environmental factors influencing phytoplankton growth are temperature, light, and nutrient availability. Phytoplankton growth is usually limited to the *photic zone*, or the depth to which sunlight penetrates the water. Other limitations to growth are nutrients such as nitrogen and phosphorous, which are prevalent in most stormwater ponds, lakes, and wetlands in North Carolina and Virginia. Phytoplankton can undergo rapid population growth or "algal blooms" when water temperatures rise in the presence of excess nutrients, which most often occurs in the spring and summer months. While increased phytoplankton populations provide more food for higher trophic level organisms, too much phytoplankton can harm the overall health of a water body. During such blooms, most of the phytoplankton die and sink to the bottom, where they decompose. This process depletes the bottom waters of dissolved oxygen, which is necessary for the survival of other organisms, such as fish, mussels, and bottom dwelling benthics.

- **Water Temperature**: Sunlight striking the surface of a pond heats the water. Fish growth rates are affected directly by water temperature. Most ponds, lakes, and wetlands in the piedmont and coastal regions of North Carolina are capable of supporting warm water fish (i.e., largemouth bass, bluegill, redbreast sunfish, channel catfish, etc.) only. Optimum growth for most warm water fish is, typically, found between 80-85 degrees Fahrenheit. Cold water fish (e.g., trout, etc.) require water temperatures between 40 and 70 degrees to spawn and live healthily. Water temperatures in the northern and mountainous regions should be monitored during the summer months. If average water temperatures in a water body begin to exceed 70 degrees for periods longer than a week, consideration should be given to increasing the vegetative shading of the pond, to creating deeper pool areas in the pond, and to modifying outlet structures such that discharges are drawn from as close to the pond bottom as practicable. These measures can aid significantly in lowering the average temperatures of the water in and leaving the pond system.
- **Oxygen:** Dissolved oxygen (DO) is the most important water quality parameter to manage. DO refers to the oxygen gas dissolved in water. Like land animals, fish cannot live without oxygen. DO concentrations in ponds must be maintained at adequate levels for fish to not only survive, but thrive. Fish absorb oxygen directly into their bloodstream using their gills. The amount of DO decreases with increases in temperature and altitude. As temperatures increase, fish metabolism increases, which causes the fish to consume more oxygen. Both the increase in temperature and the increase in fish metabolism can result in oxygen depletion in the summer. Under normal conditions, most fish need a DO concentration of about 5 parts per million (ppm), or 5 mg/L. One ppm means that for every one million parts of water, there is one part of oxygen. DO concentrations below 3 ppm stress fish, and most fish will die if DO concentrations drop below 2 ppm. For comparison, the air we breathe contains about 240,000 ppm of oxygen. Once DO levels drop below about 3 ppm, mechanical aeration may be necessary to raise DO levels. There are many varieties of mechanical aeration systems and fountains currently available on the

market. As indicated previously, oxygen is produced during the day through photosynthesis. Oxygen levels will drop at night (e.g., because photosynthesis does not occur at night), but, as with all living organisms, respiration continues. Typically, there is a balance between the oxygen produced and consumed throughout the day. There are some events, however, that can upset this balance. Provided below is a brief discussion of some of those items:

- Increased organic wastes entering the pond. Any organic material, such as manure, septic tank waste, etc., can increase the oxygen demand in the water. As these excess organic materials decay, the microorganisms facilitating the decay consume the oxygen in the water.
- Die-off of aquatic plants. Since aquatic plants are the primary source of oxygen through photosynthesis, a die-off can result in oxygen depletion. As these dead plants decompose, their decomposition requires additional oxygen.
- Excess aquatic plants. Excess plants (phytoplankton and submersed aquatic vegetation) can produce a supersaturated condition (e.g., more oxygen is produced than can be held in the water). The oxygen demand of these plants in the evening hours can result in wide fluctuations in oxygen levels.
- Water column turnovers. With stratification, a pond has two layers: a warm surface layer and cooler bottom layer. In addition, another layer is created that acts as a physical barrier between the two layers. Since photosynthesis and oxygen production only occurs near the surface, water in the cooler bottom layer becomes oxygen deficient. During heavy winds or cold rain, the barrier between the warm surface layer and the cooler bottom layer may be disrupted, causing a mixing of the two layers. If the oxygen demand is great in the oxygen-deficient bottom layer, the dissolved oxygen present in the upper layer may be rapidly removed, resulting in a fish kill.

The following are indicators that the DO in a pond may be too low:

- Fish seem to be swimming at or near the surface.
- Fish seem to be gulping for air (e.g., piping at the surface).
- Fish have stopped feeding.
- The color of the water appears to have changed rapidly to brown, black, or gray.

- **Alkalinity**: Alkalinity is a measure of the concentration of “bases” in pond water (usually, dissolved forms of carbon dioxide). Carbon dioxide is a waste product of respiration by plants and animals in a pond. Alkalinity levels that fall below 20 ppm are detrimental to fish growth and survival; maintaining levels of at least 100 ppm are optimal for good fish growth. Alkalinity levels can be increased by treating a pond with agricultural lime (calcium carbonate). A mud sample (taken from several areas of the pond bottom) should be analyzed to determine the amount of lime needed. Combine the mud samples, and spread them out to dry and take them, in soil test kit form, to the North Carolina Cooperative Extension Service (NCCES), which is located at 721 Foster Street, Durham, NC (919/560-0525). Soil test kits can be obtained from NCCES. The soil tests are performed by the NC State University Soil Testing Lab and are offered free of charge. Test results are provided in the mail. Once a liming rate has been recommended (Note: The rates should be in the 500 to 1,000 lb [or greater] per acre of water surface area), aglime (preferably in a finely ground form) should be purchased and distributed evenly over the entire pond bottom. Common methods of application include shoveling or washing it from a plywood platform mounted on a boat. The best time to apply lime is in late fall, the dead of winter, or very early in the spring. Some ponds require liming as often as every 2- to 4-years. Note that agricultural lime (aglime) should be used. Aglime, or calcium carbonate, consists of limestone crushed to a fine powder. Good quality aglime contains a calcium component that makes up about 40% of the product by weight. Do not use hydrated (builder's) lime, as it will cause a rapid pH change, due to its solubility, that may result in a fish kill. Hydrated lime is also hazardous to handle. Aglime can also aid in reducing turbidity by clearing suspended clay particles. Using lime to reduce turbidity, however, is only a temporary solution and may need to be repeated annually. Clay turbidity levels should, when possible, be kept at or below 100 mg/l.

- **Conductivity**: Conductivity or the amount of Total Dissolved Solids (TDS) is defined as the measure or quantity of dissolved material in water, and depends mainly on the solubility of the rocks and soils the water contacts. For instance, water that flows through limestone and gypsum dissolves calcium, carbonate, and sulfate, resulting in high levels of total dissolved solids. A convenient way to measure TDS is to test the conductivity of a water sample. Conductivity is a measure of the ability of water to pass an electrical current, and it is affected by the presence of dissolved solids. As TDS levels rise, so will the conductivity of the water. Discharges into water can change the conductivity depending on the nature and amount of the discharge. A failing septic system or a sanitary sewer overflow could raise the conductivity because of the presence of chloride, phosphate, and nitrate; an oil spill would lower the conductivity because oil does not conduct an electrical current very well. Conductivity is measured in micromhos per centimeter (mhos/cm) or microsiemens per centimeter (s/cm), equivalent units of measure that can be used interchangeably. Distilled water has a conductivity in the range of 0.5 to 3 mhos/cm. Conductivity increases with decreasing water purity. This fact is useful in numerous industrial, sanitation, purification, and control applications, as conductivity measurement provides useful information as to the behavior or scaling/deposition/foaming tendencies of the water.
- **Hardness**: Hardness is a measure of the "divalent" or cationic bases (mostly calcium and magnesium) in pond water. These bases combine with carbonate and bicarbonate ions in relatively insoluble forms, which make them good buffers against rapid fluctuations in pH. Soft waters generally have low alkalinities and have little calcium and magnesium and, consequently, are more susceptible to acidification. Hard waters usually have high calcium concentrations and are far less susceptible to acidification. A hardness level of greater than 20 ppm is considered beneficial for good fish growth. Hardness levels can be increased by treating a pond with aglime.

- **pH**: The pH of water is an expression of its acid or base content. The pH scale ranges from 0 (very acidic) to 14 (very basic). For example, battery acid has a pH of 0.3, and lye, a pH of 13.8. Both compounds are very caustic to human and aquatic life. Most natural lake waters range from a pH of 6 to 9 and are generally more on the basic side of the scale due to the presence of carbonates. The addition of aglime will raise the pH of the water.
- **The Benefits of Aglime**: As alluded to above, the addition of aglime to a pond will result generally in the following benefits: acid neutralization; increased pH; increased alkalinity; increased calcium (e.g., water hardness); improved fish production; increased biodiversity; decreased turbidity; and decreased toxic metals in the water column.

Plantings and Vegetation

An often overlooked item in the maintenance of a stormwater pond or wetland is the care of the trees, shrubs, grasses, and other plantings that are growing (or trying to grow) in the impoundment area of a pond. Not only do such plantings perform a key water quality function in that they filter out and soak up pollutants, but they also provide food and cover for wildlife and add immense interest and aesthetic value to the pond landscape.

The introduction (or reintroduction) of wetland and wet meadow plantings to any pond, even a "dry" pond, can improve markedly the aesthetic, water quality treatment, and wildlife habitat aspects of the facility. Many wetland plant species will perform well in water depths of up to 12". Cattails (*Typha sp.*), which are natural (and, in many instances, beneficial) to a wetland environment, can sometimes choke out other, more desirable vegetation. As such, cattails should be controlled in the early phases of colonization by bending and wiping each stalk with aquatic formulations of the systemic herbicide glyphosate. Please refer to the sections below regarding the regulated control of invasive vegetation.

To maintain a dense, herbaceous, vegetative state in your pond or wetland (e.g., to keep it in a "suspended state of adolescence"), avoid planting large shrubs or trees that tend to shade out herbaceous species. Larger trees and shrubs should, for the most part, be reserved for those areas that surround the pond. Trees, such as river birch, red maple, sycamore, and swamp cypress will do well in a wetland area, and eastern redbud and sweet bay magnolia can provide significant aesthetic interest in the zones surrounding a pond or wetland (e.g., upper bank areas). When planting trees in a wetland, a tree density of no more than 3 to 4 trees per 10,000 square feet of wetland surface area is recommended. "Volunteers" should be limited, and any invasive trees, such as black willow, should be eliminated as soon as practicable. With respect to the introduction (or reintroduction) of herbaceous plants to a stormwater pond or wetland, provided below, are two lists of suggested wetland/wet meadow plants that appear to colonize well and survive in such devices.

Given the complex nature of wetland plant selection and ecotyping, planting, care, and maintenance as well as how such plants respond to various permanent and intermittent pooling levels, it is recommended that all significant plant activities be conducted under the watchful guidance of a registered Professional Engineer and a wetland ecologist or local landscape specialist with particular expertise in wetland planting and management.

Depending on the time of year and rainfall amounts, supplemental watering of landscape elements may be required. When a potable water source is not readily available (or even if it is) and the pond contains a permanent pool of water, it is recommended that a sump pump watering system be implemented, where water is drawn from the pond to irrigate the newly seeded areas. During extreme droughts, it may be necessary to contract out the trucking in of reclaimed wastewater from a nearby wastewater treatment facility. It should be noted that, in most instances, it will be cheaper to provide such supplemental watering than to replant landscaping that has died off due to insufficient moisture.

Internal Wetland Zones Defined

(Source: Dr. Bill Hunt, Assistant Professor and Extension Specialist, Biological and Agricultural Engineering Department, NCSU)

Zone 1: Deep Pool: 18- to 48-inch normal pool water depths
Zone II: Deep Pool-to-Shallow Water Transition: 6- to 18-inch normal pool water depths
Zone III: Sallow Water: 0- to 6-inch normal pool water depths
Zone IV: Temporary Inundation: Water quality temporary pool areas (e.g., 0-inch normal pool water depths to approximately 12-inches above normal pool)
Zone V: Upper Bank: Pool areas above the water quality temporary pool

Tier 1 Table - Stormwater Wetland Vegetation

Plants Found to Reliably Colonize in Stormwater Wetlands from the Highest to Least Water Tolerant

(Source: Dr. Bill Hunt, Assistant Professor and Extension Specialist, Biological and Agricultural Engineering Department, NCSU)

Common Name	Scientific Name	Zone/s	Comments
Fragrant Water Lily	*Nymphaea odorata*	I and II (deepest fringe)	
Spatterdock	*Nuphar lutea*	I and II (deepest fringe)	
Softstem Bulrush	*Schoeneplectus tabernaemontani*	II and III	Former Scientific Name: *Scirpus Validus*
Pickerelweed	*Pontedaria cordata*	II and III	Produces a bright and showy purple/blue flower.
Broadleaf Arrowhead	*Sagittaria latifolia*	III	Produces broad leaves, and produces white flowers in the summer.
Bulltongue Arrowhead	*Sagittaria lancifolia*	III	Produces white flowers in the

			summer.
Burreed or Bur-reed	*Sparganium spamericanum*	III	Tolerates flowing water zones near inlets and outlets.
Lizard's Tail	*Saururus cernuus*	III and IV	Can dominate in dryer years; produces a distinctive thin white flower.
Woolgrass	*Scirpus cyperinus*	III and IV	Produces a tall, brown seed head in the summer. Makes tall border.
Common Rush	*Juncus spp.*	III and IV	Grows best at the water's edge. Grows well near evergreens in the Coastal Plain and Piedmont (eastern portions) regions.

Tier 2 Table - Stormwater Wetland Vegetation

Plants Found to Survive in Stormwater Wetlands, Often Adding Color, from the Highest to Least Water Tolerant

(Source: Dr. Bill Hunt, Assistant Professor and extension Specialist, Biological and Agricultural Engineering Department, NCSU)

Common Name	**Scientific Name**	**Zone/s**	**Comments**
Water (American) Lotus	*Nelumbo lutea*	I and II (edge)	Protrudes from deep pools. Good for mountain wetlands. There is some concern that this plant is too aggressive.
Arrow Arum	*Peltandra virginica*	III	Similar is appearance to *Sagittaria*.
Swamp Milk Weed	*Asclepias incarnata*	III and IV	Produces an orange flower in the fall.
Blue Flag Iris	*Iris virginica or versicolor*	III and IV (edge)	Produces a showy blue (or other color) flower in late spring. Grows at the water's edge.
Sedge	*Carex spp.*	III and IV	There are many

			species available. This plant is a good initial colonizer.
Cardinal Flower	*Lobelia cardinalis*	IV	Produces brilliant red flowers in late summer.
Hibiscus (Rose Mallow)	*Hibiscus moscheutos and grandiflorus*	IV	Produces beautiful, showy white and red flowers in mid/late summer.
Swamp Rose	*Rosa palustris*	IV	Produces an off-white bloom in the spring.
Joe Pye Weed	*Eupatorium purpureum*	IV and V	Produces a purple-like bloom in the summer and fall.

Note: The denser the initial planting, the more quickly the vegetation will establish, and the less likely invasive species will dominate a stormwater pond or wetland. For most of the plants listed above, a planting density of about one plant on 24-inch centers (one plant/four square feet) is recommend if the goal is full colonization within twelve months of planting. A planting density of one plant on 36-inch centers (one plant/nine square feet) should produce a fully colonized wetland within 24 months. To minimize invasive species colonization, the minimum planting density should be at least one plant/nine square feet; lesser planting densities may result in a monoculture of invasive plants that may overtake or prevent the effective colonization of desired vegetation.

Invasive or Excess Aquatic Vegetation

The presence of invasive and/or excess aquatic vegetation can pose significant problems to the environment and to the function of a stormwater pond. In most instances, selective vegetative control, as opposed to complete eradication, may be sufficient to ensure adequate pond function. The decision to proceed with total eradication will be made based on discussions between the BMP owner, the BMP owner's consultant, and the Stormwater Services Division. All invasive or excess aquatic vegetative control or eradication efforts shall typically be done mechanically or biologically (i.e., with floating wetlands, etc.). The use of aquatic herbicides will be permitted by the Stormwater Services Division on a case-by-case basis. Under no circumstances will the use of dyes or colorant be approved for use in a stormwater pond.

Aquatic Herbicides

The use of herbicides will require site specific approval by the Stormwater Services Division. Whenever the use of an herbicide is proposed, only EPA approved aquatic formulations of such an herbicide shall be used. Again, it should be understood that the use of any herbicides in a stormwater pond will require the site specific approval of the Stormwater Services Division. THE USE OF ANY NON AQUATIC HERBICIDES, OR THE USE OF ANY AQUATIC HERBICIDES WITHOUT THE

PREVIOUS AND SITE SPECIFIC APPROVAL OF THE STORMWATER SERVICES DIVISION, SHALL BE STRICTLY PROHIBITTED. VIOLATORS OF THIS PROHIBITION WILL BE PROSECUTED TO THE MAXIMUM EXTENT PERMITTED BY LAW. It should be noted that the use of any aquatic herbicides will always require the submittal of a vegetative control and eradication plan (VCEP) that delineates, on a scaled drawing, the locations of the top three or four species of invasive or excess aquatic vegetation proposed to be controlled or eradicated. In addition, the submittal of a vegetative replanting plan (VRP), also a scaled drawing, will be required. Both the VCEP and VRP will require approval by the Stormwater Services Division prior to commencing any such work. A final report of all aquatic herbicide usage shall be included with the annual maintenance certification submitted for the specific pond in which said herbicides were used.

Banned Chemicals

The following chemicals are hereby BANNED from use in stormwater ponds in the City of Durham:

1. Non aquatic herbicides;
2. Aquatic herbicides not approved by the EPA;
3. Dyes or colorants;
4. Copper sulfate; and
5. Copper sulfate with a dye or colorant component.

Mosquitoes

(Primary Source: *Stormwater Management and Mosquito Ecology*, John R. Wallace. Stormwater: The Journal for Surface Water Quality Professionals, March/April 2007 Issue)

When water is impounded, either permanently or intermittently, invariably, the following question will arise: “Do I need to worry about mosquitoes and standing water?” Categorically, the answer is: YES. Because stormwater ponds and other BMPs hold standing water, their potential for producing a mosquito breeding habitat is high; consequently, their design and maintenance is important in reducing public health risks and concerns associated with the West Nile Virus (WNV) and other arthropod-borne viruses (arboviruses) such as Eastern Equine Encephalitis and LaCrosse Encephalitis.

There are over 3,500 breeds of mosquitoes in the world, of which, about 175 can be found in the United States and over 50 can be found in North Carolina. Without exception, all mosquitoes require an aquatic habitat such as a pond, marsh, treehole, tire, natural or artificial container, crabhole, or artificially created system, such as a stormwater pond or other kind of stormwater BMP. At certain times of the year, in many areas of the United States, mosquitoes are formidable nuisance biting insects. However, it should be noted that many mosquitoes that are nuisance biters are not vectors of WNV or other arboviruses and that many of these mosquitoes do not use stormwater BMPs as their larval habitat. Thus, because complaints of nuisance biting mosquitoes and concerns about WNV transmission may involve mosquitoes that don’t inhabit stormwater BMPs, abatement or control should, where BMPs are concerned, focus on the mosquito larvae that reside in a stormwater BMP.

Research in the last few years has shown that the following four mosquito species have been identified as potential vectors of WNV: (1) *Culex restuans* (vector among birds); (2) *Culex pipiens* (vector among birds); (3) *Culex salinarius* (potential “bridge” vector between birds and mammals [humans]); and (4) *Aedes vexans* (potential "bridge" vector between birds and mammals [humans]). Note: To date, it has not been demonstrated conclusively that the Asian Tiger Mosquito (*Aedes albopictus*), which is another common nuisance biter, is a vector for WNV. These research studies have found also that the above mosquitoes, while they may be present in stormwater ponds, represent only a very small number of the mosquitoes that populate such devices. In fact, the four breeds mentioned above are often forced out of (or eliminated from) pond environments by natural predatory controls (e.g., frogs, dragonflies, damselflies, water striders, salamanders, goldfish, fathead minnows, and other fish) as well as other breeds of mosquito, many of which are not nuisance biters.

Since each pond is different, each pond should be evaluated for possible mosquito infestation. Typically, the priority should be directed at ponds that are located within close proximity to hospitals, schools, and retirement homes (facilities that house or congregate those members of the population that pose the greatest risk of arboviral infection), and each pond should be evaluated to determine if current mosquito activity is exceeding what could be coined a "threshold limit" of activity such that treatment would be required to reduce a potential public health risk.

Threshold levels for treatment should be established by one of two methods. One is by field sampling and determining if larval numbers exceed an average of 20 larvae per dip (based on a 50-dip minimum) of the BMP in question. (Note: This number was established based on anecdotal evidence that when larval numbers exceeded this threshold, nuisance [e.g., biting] adult mosquitoes seemed to be in abundance.) The other method for establishing threshold levels for treatment is by monitoring the number of formal complaints registered by the public or by maintenance workers responsible for the on-going maintenance and operation of BMP facilities. It is not necessary that all BMPs be treated with bacterial larvicides, only those identified through monitoring or complaint calls.

If pesticide use is required, there are many options available, both chemical and biological, to control larval mosquitoes. However, it should be noted that the bacterial larvicides that have been used in recent years have provided an effective, environmentally friendly, and cost-effective approach to controlling mosquitoes in BMPs. As such, it is recommended that Bti (*Bacillus thuringiensis* subspecies *israelensis*) or Bs (*Bacillus sphaericus*) be used, as these bacterial larvicides will control mosquito, as well as black fly and midge, larvae effectively, with minimal harm to water quality or non-targeted invertebrates.

Summit Chemical Company (www.summitchemical.com) manufactures *Mosquito Dunks*, a commercially available Bti product that can be used readily by property owners to treat stormwater ponds for mosquito larvae. Each dunk can treat up to 100 square feet of water surface area for up to 30 days. Home Depot and other stores carry the product at a cost of approximately $1.50 each. Since female mosquitoes can breed multiple times a year, a pond that requires treatment should be treated for the entire length of the breeding season. Depending on the climate, the mosquito breeding season in North Carolina can last anywhere from mid February/early March to late October/mid November (e.g., about 6- to 8-months).

THE BOTTOM LINE: While the spread of WNV is a concern, as a matter of comparison, according to the 2007 Flyer, "Flu Vaccine Facts & Myths," prepared by the

Centers for Disease Control (CDC), each year in the US, approximately 36,000 people die form the flu. For calendar year 2006, the CDC reported that 177 people in the US died from WNV, and that there were no deaths reported in North Carolina, South Carolina, or Virginia. Only a very small percentage (less than 1%) of people bitten by a WNV infected mosquito will even show clinical (e.g., mild flu-like) symptoms of the disease; far less than that (<<1%) will become seriously ill or die from it.

<u>SECTION 2</u>

UNDERGROUND DETENTION SYSTEMS

FUNCTIONAL ELEMENTS

Definition of Device Type

Underground Detention System: An underground detention system is a constructed stormwater device that temporarily stores incoming stormwater underground and, through its storage capacity, reduces the frequency and severity of downstream flooding and erosion.

Glossary of Primary Elements

By-Pass Structure: A structure that forces emergency flows to by-pass the system all together. The intent of a by-pass structure is to reduce the amount of hydrostatic pressure on the system and to mitigate the flooding of the upstream drainage area due to the system backing up too much water.

By-pass (Emergency) Weir: A wall in the control structure that allows emergency flows to exit the system. As with a by-pass structure, the intent of a by-pass weir is to reduce the amount of hydrostatic pressure on the system and to mitigate the flooding of the upstream drainage area due to the system backing up too much water.

> Note: All underground detention systems should have either a by-pass structure or an emergency (by-pass) weir in the control structure. If such a device does not exist, consultation with a registered Professional Engineer to evaluate the potential for installing such a device is recommended.

Control Structure: The principal water release structure in the system. This is the structure that regulates the rate at which stormwater exits the system.

Detention Chambers/Pipes: A collection of pipes or chambers that intermittently stores stormwater in the system.

Inlet: A pipe or drop inlet structure that discharges collected stormwater into the detention chambers/pipes for the system.

Outfall: The point where water leaves the system and enters the downstream drainage system.

Principal Spillway Pipe: The principal pipe that coveys water from the control structure to the outfall.

MAINTENANCE REQUIREMENTS

Erosion and Sediment Control Requirements

Please refer to **Section 2: Stormwater Ponds**.

Control Structure Maintenance

Blockages

All trash, sediment, and debris blocking the entry or passage of storm flows into or through the control structure should be removed.

Structural Integrity

Depending on the severity of the deterioration, the control structure may need to be replaced. If the overall integrity of the structure is reasonably sound, the following repairs should be considered:

- Cracks should be sealed with an epoxy low-shrink grout.
- Spalled areas should be repaired with a two-part cement-bonding agent and then painted.
- Rusted areas, if reparable, should be scraped, cleaned, primed, painted with two coats of rust-resistant paint, and, if appropriate, coated with a bituminous sealant.

Insufficient Debris Management

If the structure clogs routinely to a point where stormwater continues to stay in the system for longer periods than thee days, it may mean that the low-flow orifice at the bottom of the control structure may require a trashrack to mitigate the clogging of the device. Typical details for such racks can be obtained from the Stormwater Services Division.

Detention Chamber/Pipe Maintenance

Trash, Sediment, and Debris

All trash, sediment, and debris should be removed from the detention chambers/pipes at least twice a year or more frequently if the amount of accumulated material warrants such a practice.

Leaking and Misaligned Pipe Joints

Even though underground detention systems are supposed to remain water tight, it is not uncommon for some of the pipe joints to begin to leak. Usually, a leaking pipe joint is not a great concern unless soil material from outside the pipe is infiltrating the system. The progressive infiltration of the soil into the system could result in a cave-in over the pipe, which could damage parking and travel surfaces that may lie on top of the system. Leaking pipes, which are allowing the infiltration of soil into the system, should be repaired as soon as practicable. Concrete pipe joints should be cleaned and sealed with a low-shrink epoxy grout. Metal pipe joints should be cleaned, and a non hydro-phobic waterproofing sealant should be injected into the open gap(s) in the pipe joint.

Separated Pipe Joints

Depending on the severity, separated pipe joints could, conceivably, be repaired in a manner similar to that described above. In many instances, however, it may be necessary to expose the joint from the outside and then “diaper” it with a felt wrap (or neoprene in the instance of corrugated metal pipe [CMP]), flashing (or banding in the instance of CMP), and concrete. In severe separations, the separated pipes may need to be removed, the subbase support rebuilt, and the pipes relayed or replaced prior to the diapering operation described above. Consultation with a registered Professional Engineer is recommended to assess the severity of the problem and devise a workable solution to correct or repair the problem.

Crushed, Collapsed, or Rusted-out Sections of Pipe

In most instances, a pipe in this condition should be removed and replaced under the supervision of a registered Professional Engineer.

Mosquitoes

Underground detention systems are prime locations for mosquito breeding. For an in depth discussion of mosquito issues and mosquito abatement strategies, please refer to **Section 1: Stormwater Ponds**.

Outfall Area Maintenance

Blockages

A blocked outfall channel should be opened up as soon as practicable, especially if the channel is backing a significant amount of water up inside the control structure or detention chambers/pipes. Typically, outfall channels should be cleared of trees for a distance, downstream from the outfall structure, of at least 5 times the diameter of the principal spillway pipe. For example, the clearing area for a 36” (three-foot) diameter outlet pipe would be 15-feet long. Note: Established vegetation and trees on the stream banks should be left in place. The “clearing” should be limited to the removal of dead and fallen trees and anything in the flow-line of the channel that significantly prevents water from exiting the pond facility.

Erosion

Eroded outfall channels should be repaired as soon as practicable with additional riprap armoring or other permanent lining material.

Inlet Maintenance

Inlets

Inlets to the underground detention system should be kept open and in good working condition. All eroded areas should be repaired.

By-Pass Structure Maintenance

Blockages

All trash, sediment, and debris blocking the entry or passage of storm flows through the structure or into the underground detention system should be removed.

Structural Integrity

Depending on the severity of the deterioration, the bypass structure may need to be replaced. If the overall integrity of the structure is reasonably sound, the following repairs should be considered:

- Cracks should be sealed with an epoxy low-shrink grout.
- Spalled areas should be repaired with a two-part cement-bonding agent and then painted.
- Rusted areas, if reparable, should be scraped, cleaned, primed, painted with two coats of rust-resistant paint, and, if appropriate, coated with a bituminous sealant.

<u>SECTION 3</u>

OPEN SAND FILTERS

FUNCTIONAL ELEMENTS

Definition of Device Type

Open Sand Filter: An open sand filter is an above ground constructed stormwater device that allows stormwater to percolate down through a sand layer that filters out sediments and other pollutants.

Glossary of Primary Elements

By-Pass Structure: A structure that forces emergency flows to by-pass the system all together. The intent of a by-pass structure is to reduce the amount of hydrostatic pressure on the system, to reduce the potential for overwhelming the stormwater treatment device, and to mitigate the flooding of the upstream drainage area due to the system backing up too much water. Because an open sand filter has, in most instances, a dam embankment of sorts, the intent of a by-pass structure is also to reduce the chances of dam overtopping.

Dam: An earthen embankment or wall (or some combination of the two) that creates an intermittent water impoundment.

Emergency Spillway: A supplemental channel or structure that routes emergency storm flows around or through an earthen embankment dam. In the instance of a concrete dam, the emergency spillway may be a lower-level weir intended to provide release of emergency flows to protect the dam during large storm events. The intent of an emergency spillway is to lower the chances of dam overtopping.

Flow-through Weir or Pipe: A device that allows water in the sediment chamber to flow into the sand chamber.

Inlet: A pipe or channel that discharges collected stormwater into the sediment chamber of an open sand filter.

Outfall: The point where water leaves an open sand filter and enters the downstream drainage system.

Principal Spillway Pipe: The principal pipe that coveys water from the riser to the outfall.

Riser: The principal water release structure in an open sandfilter. This is the structure that regulates, to a degree, the rate at which stormwater exits the system. Sometimes, a riser in an open sandfilter may be configured more like a weir wall structure than a true riser structure.

Sand Filter Bed: A bed of sand (clean, ASTM C-33 concrete "builder's" sand), which is typically about 18" deep, through which water entering the sand chamber drains and is treated for pollutants.

Sand Filter Chamber: A depression, sometimes lined with earth or concrete, that contains the sand filter bed and the underdrains.

Sediment Chamber: A depression (sometimes lined with earth, rock, or concrete) into which all inlets to the device discharge. The purpose of the sediment chamber is to capture particulate pollutants, such as small stones, sand, and heavy sediment. Some sediment chambers are designed to maintain a permanent pool of water, and some are not.

Underdrain: A perforated drain pipe in the bottom of the sand filter bed, which allows filtered water to exit the sand filter. The underdrains are connected to the riser structure.

MAINTENANCE REQUIREMENTS

Because an open sand filter is, in a number of ways, similar to a small stormwater pond, many of the maintenance requirements will resemble those provided in **Section 1: Stormwater Ponds**. In several of the maintenance requirements provided below, reference will be made to maintenance requirements discussed previously in **Section 1: Stormwater Ponds**.

Erosion and Sediment Control Requirements

Please refer to **Section 2: Stormwater Ponds**.

Dam Embankment/Emergency Spillway Maintenance

Please refer to **Section 2: Stormwater Ponds**.

Riser Structure Maintenance

Please refer to **Section 2: Stormwater Ponds**.

Principal Spillway Pipe (PSP) Maintenance

Please refer to **Section 2: Stormwater Ponds**.

Outfall Structure Maintenance

Please refer to **Section 2: Stormwater Ponds**.

Outfall Area Maintenance

Please refer to **Section 2: Stormwater Ponds**.

Impoundment Area Maintenance

<u>Trash and Debris in Sediment Chamber</u>

All trash and debris should be removed from the sediment chamber on a regular basis. Depending on the characteristics of the drainage area to the facility, the sediment chamber may need to be cleaned of accumulated trash and debris on a monthly basis.

<u>Sedimentation of Sediment Chamber</u>

Once a significant portion of the sedimentation chamber has filled-in (approximately 25-30% by volume), the chamber should be cleaned/dredged. Typically, sediment chambers will need to be cleaned out once every 3- to 5-years. Note: The North Carolina Department of Environment and Natural Resources, Division of Water Quality (919/733-7015) or Division of Waste Management/Hazardous Waste Services

(919/508-8400), should be contacted regarding the proper testing and disposal of dredged material if it is to be hauled off-site.

Inlets

Inlets to the open sand filter should be kept open and in good working condition, and all eroded areas should be repaired. It should be noted that all inlets to the sand filter should drain to the sediment chamber. If one or more inlets are draining directly into the sand filter bed and are by-passing the sediment chamber, it is recommended that you consult with a registered Professional Engineer to assess this condition. Inlets that by-pass the sediment chamber may cause the sand filter bed to clog prematurely.

Blockage of Flow-through Weir or Pipe

All trash and debris blocking the entry or passage of storm flows into or through the flow-through weir or pipe should be removed.

Erosion of Earthen Flow-through Weir

Sometimes, due to fluctuations in pool depths, incoming flows may erode a portion of the earthen flow-through weir or may create a scour hole in the surface of the sand filter bed. An eroded weir and or scour hole should be repaired as soon as practicable. The installation of riprap (or additional riprap) may be required. The riprap should be taken all the way to the surface of the sand filter bed.

Vegetation in Sand Filter Bed

All vegetation growing in the sand filter bed, unless specific vegetative plantings were a requirement of the design, should be removed. Any sand that is removed should be replaced with clean sand that meets the specifications for the sand filter bed design.

Trash and Debris in Sand Filter Chamber

All trash and debris should be removed from the sand filter chamber on a regular basis.

Sedimentation (or Clogging) of Sand Filter Bed

If the sand filter is holding water for a period longer than three days, the sand filter has, more than likely, become clogged with sediment. To gage the extent of contamination, it is recommended that one or more test pits be dug with a shovel and that the sand layer be evaluated for contamination. Once the levels of contamination have been determined (for example, the top 4” of sand appear to be contaminated), it is recommended that the contaminated sand plus two additional inches of sand be removed and replaced with clean sand that meets the specifications for the sand filter bed design. (Note: If it appears that the entire sand bed is contaminated, the entire sand filter layer and underdrain system should be removed and replaced.) If, after completing the above removal and replacement of contaminated sand, the sand filter still continues to hold water, it may be that the sand filter layer has reached the end of its functional life and/or that the underdrains have become clogged. If this is the case, the sand filter layer and the underdrains should be removed and replaced. Reuse of any undamaged underdrains may be possible once they have been cleaned thoroughly.

Damaged Concrete Impoundment Walls

Many open sand filters are contained in concrete impoundment walls. These walls should be inspected regularly for damage. Minor cracks and spalled areas should be repaired as soon as practicable. If more significant damage is apparent (i.e., one wall is beginning to lean or has settled significantly, etc.), consultation with a registered Professional Engineer is recommended.

Provision of Fall Protection around Impoundment Walls

To protect the general public and maintenance personnel, it is recommended that handrailing or fencing be provided around the perimeter of the impoundment walls. Gated access points should be provided so that maintenance personnel will be able to enter the facility and perform needed maintenance functions.

Mosquitoes

For a discussion of mosquito issues, please refer to **Section 1: Stormwater Ponds**.

SECTION 4

CLOSED SAND FILTERS

FUNCTIONAL ELEMENTS

Definition of Device Type

Closed Sand Filter: A closed sand filter is a below ground constructed stormwater device that allows stormwater to percolate down through a sand layer that filters out sediments and other pollutants.

Glossary of Primary Elements

By-Pass Structure: A structure that forces emergency flows to by-pass the system all together. The intent of a by-pass structure is to reduce the amount of hydrostatic pressure on the system, to reduce the potential of overwhelming the stormwater treatment device, and to mitigate the flooding of the upstream drainage area due to the system backing up too much water.

By-pass (Emergency) Weir: A weir wall in the control structure that allows emergency flows to exit the system. As with a by-pass structure, the intent of a by-pass weir is to reduce the amount of hydrostatic pressure on the system and to mitigate the flooding of the upstream drainage area due to the system backing up too much water.

> Note: All closed sand filter systems should have either a by-pass structure or an emergency (by-pass) weir in the control structure. If such a device does not exist, consultation with a registered Professional Engineer to evaluate the potential for installing such a device is recommended.

Control Structure: The principal water release structure in the system. This is the structure that, to a degree, regulates the rate at which stormwater exits the system.

Flow-through Slot or Pipe: A device that allows water in the sediment chamber to flow into the sand chamber.

Inlet: A pipe, channel, or collection device (i.e., grate inlet, etc.) that discharges collected stormwater into the sediment chamber of a closed sand filter.

Outfall: The point where water leaves a closed sand filter and enters the downstream drainage system.

Principal Spillway Pipe: The principal pipe that coveys water from the control structure to the outfall.

Sand Filter Bed: A bed of sand (clean, ASTM C-33 concrete “builder’s” sand), which is typically about 18” deep, through which water entering the sand chamber drains and is treated for pollutants.

Sand Filter Chamber: A chamber, usually concrete, which houses the sand filter bed and the underdrains.

Sediment Chamber: A chamber, usually concrete, into which all inlets to the device discharge. The purpose of the sediment chamber is to capture particulate pollutants, such as small stones, sand, and heavy sediment. Some sediment chambers are designed to maintain a permanent pool of water, and some are not.

Underdrain: A perforated drain pipe in the bottom of the sand filter bed, which allows filtered water to exit the sand filter. The underdrains are connected to the control structure.

MAINTENANCE REQUIREMENTS

Erosion and Sediment Control Requirements

Please refer to **Section 2: Stormwater Ponds**.

Control Structure Maintenance

Blockages

All trash, sediment, and debris blocking the entry or passage of storm flows into or through the control structure should be removed.

Structural Integrity

Depending on the severity of the deterioration, the control structure may need to be replaced. If the overall integrity of the structure is reasonably sound, the following repairs should be considered:

- Cracks should be sealed with an epoxy low-shrink grout.
- Spalled areas should be repaired with a two-part cement-bonding agent and then painted.
- Rusted areas, if reparable, should be scraped, cleaned, primed, painted with two coats of rust-resistant paint, and, if appropriate, coated with a bituminous sealant.

Impoundment Area Maintenance

Trash and Debris in Sediment Chamber

All trash and debris should be removed from the sediment chamber on a regular basis. Depending on the characteristics of the drainage area to the facility, the sediment chamber may need to be cleaned of accumulated trash and debris on a monthly basis.

Sedimentation of Sediment Chamber

Once a significant portion of the sedimentation chamber has filled-in (approximately 25-30% by volume), the chamber should be cleaned/dredged. Typically, sediment chambers will need to be cleaned out once every 3- to 5-years. Note: The North Carolina Department of Environment and Natural Resources, Division of Water Quality (919/733-7015) or Division of Waste Management/Hazardous Waste Services (919/508-8400), should be contacted regarding the proper testing and disposal of dredged material if it is to be hauled off-site.

Blockage of Flow-through Slot or Pipe

All trash and debris blocking the entry or passage of storm flows into or through the flow-through slot or pipe should be removed.

Trash and Debris in Sand Filter Chamber

All trash and debris should be removed from the sand filter chamber on a regular basis.

Sedimentation (or Clogging) of Sand Filter Bed

If the sand filter is holding water for a period longer than three days, the sand filter has, more than likely, become clogged with sediment. To gage the extent of contamination, it is recommended that one or more test pits be dug with a shovel and that the sand layer be evaluated for contamination. Once the levels of contamination have been determined (for example, the top 4" of sand appears to be contaminated), it is recommended that the contaminated sand plus two additional inches of sand be removed and replaced with clean sand that meets the specifications for the sand filter bed design. (Note: If it appears that the entire sand bed is contaminated, the entire sand filter layer and underdrain system should be removed and replaced.) If, after completing the above removal and replacement of contaminated sand, the sand filter still continues to hold water, it may be that the sand filter layer has reached the end of its functional life and/or that the underdrains have become clogged. If this is the case, the sand filter layer and the underdrains should be removed and replaced. Reuse of any undamaged underdrains may be possible once they have been cleaned thoroughly.

Damaged Concrete Chamber Walls

The walls of each chamber should be inspected for damage. Minor cracks and spalled areas should be repaired as soon as practicable. If more significant damage is apparent, consultation with a registered Professional Engineer is recommended.

Mosquitoes

For a discussion of mosquito issues, please refer to **Section 1: Stormwater Ponds**.

Outfall Area Maintenance

Blockages

A blocked outfall channel should be opened up as soon as practicable, especially if the channel is backing a significant amount of water up inside the PSP. Typically, outfall channels should be cleared of trees for a distance, downstream from the outfall structure, of at least 5 times the diameter of the PSP. For example, the clearing area for a 36" (three-foot) diameter PSP would be 15-feet long. Note: Established vegetation and trees on the stream banks should be left in place. The "clearing" should be limited to the removal of dead and fallen trees and anything in the flow-line of the channel that significantly prevents water from exiting the pond facility.

Inlet Maintenance

Inlets

Inlets to the closed sand filter should be kept open and in good working condition, and all eroded areas should be repaired. It should be noted that all inlets to the sand filter should drain to the sediment chamber. If one or more inlets are draining directly into the sand filter bed and are by-passing the sediment chamber, it is recommended that you consult with a registered Professional Engineer to assess this condition. Inlets that by-pass the sediment chamber may cause the sand filter bed to clog prematurely.

By-Pass Structure Maintenance

<u>Blockages</u>

All trash, sediment, and debris blocking the entry or passage of storm flows through the structure or into the sand filter should be removed.

<u>Structural Integrity</u>

Depending on the severity of the deterioration, the bypass structure may need to be replaced. If the overall integrity of the structure is reasonably sound, the following repairs should be considered:

- Cracks should be sealed with an epoxy low-shrink grout.
- Spalled areas should be repaired with a two-part cement-bonding agent and then painted.
- Rusted areas, if reparable, should be scraped, cleaned, primed, painted with two coats of rust-resistant paint, and, if appropriate, coated with a bituminous sealant.

<u>SECTION 5</u>

BIORETENTION AREAS

FUNCTIONAL ELEMENTS

Definition of Device Type

Bioretention Area: A bioretention area is a constructed open depression, where plants and soils are used to provide treatment for stormwater. Though the biological processes are different, a bioretention area performs in a manner similar to an open sand filter in that the device allows stormwater to percolate down through a sand/soil layer that filters out sediments and other pollutants.

Glossary of Primary Elements

Bioretention Soil Mix: A two- to four-foot deep mix of soil.

By-Pass Structure: A structure that forces emergency flows to by-pass the system all together. In a bioretention area, the by-pass structure may be a simple diversion structure located in a curb cut. It is not uncommon for there to be several such structures associated with a bioretention area. The intent of a by-pass structure is to reduce the amount of hydrostatic pressure on the system, to reduce the potential of overwhelming the stormwater treatment device, and to mitigate the flooding of the upstream drainage area due to the system backing up too much water. Because a bioretention area sometimes contains a dam embankment of sorts, the intent of a by-pass structure is also to reduce the chances of dam overtopping.

Dam: An earthen embankment or wall (or some combination of the two) that creates an intermittent water impoundment.

Emergency Spillway: A supplemental channel or structure that routes emergency storm flows around or through an earthen embankment dam. The intent of an emergency spillway is to lower the chances of dam overtopping.

Forebay or Sediment Basin: A depression (sometimes lined with rock) at an inlet, which is intended to capture particulate pollutants, such as small stones, sand, and heavy sediment.

Inlet: A pipe or channel that discharges collected stormwater into a bioretention area.

Inlet Level-Spreader: A device intended to spread or distribute flows entering a bioretention area.

Mulch Layer: A two- to three-inch layer of double-shredded hardwood mulch. The mulch layer is intended to completely cover the bioretention soil mix.

Outfall: The point where water leaves an open sand filter and enters the downstream drainage system.

Principal Spillway Pipe: The principal pipe that coveys water from the riser to the outfall.

Riser: The principal water release structure in a bioretention area. This is the structure that regulates, to a degree, the rate at which stormwater exits the system.

Underdrain: A perforated drain pipe in the bottom (or near the bottom) of the soil mix, which allows filtered water to exit the bioretention area. The underdrains may be connected to a riser structure, or, if no riser is present, may be daylighted downstream of the device.

MAINTENANCE REQUIREMENTS

Because a bioretention area is, in a number of ways, similar to a small stormwater pond, many of the maintenance requirements will resemble those provided in **Section 1: Stormwater Ponds**. In several of the maintenance requirements provided below, reference will be made to maintenance requirements discussed previously in **Section 1: Stormwater Ponds**.

Erosion and Sediment Control Requirements

Please refer to **Section 2: Stormwater Ponds**.

Dam Embankment/Emergency Spillway Maintenance

Please refer to **Section 2: Stormwater Ponds**.

Riser Structure Maintenance

Please refer to **Section 2: Stormwater Ponds**.

Principal Spillway Pipe (PSP) Maintenance

Please refer to **Section 2: Stormwater Ponds**.

Outfall Structure Maintenance

Please refer to **Section 2: Stormwater Ponds**.

Outfall Area Maintenance

Please refer to **Section 2: Stormwater Ponds**.

Impoundment Area Maintenance

<u>Trash and Debris in Forebay/Sediment Basin</u>

All trash and debris should be removed from the sediment basin on a regular basis. Depending on the characteristics of the drainage area to the facility, the sediment basin may need to be cleaned of accumulated trash and debris on a monthly basis.

<u>Sedimentation of Forebay/Sediment Basin</u>

Once a significant portion of the sediment basin has filled-in (approximately 25-30% by volume), the chamber should be cleaned. Note: The North Carolina Department of Environment and Natural Resources, Division of Water Quality (919/733-7015) or Division of Waste Management/Hazardous Waste Services (919/508-8400), should be contacted regarding the proper testing and disposal of dredged material if it is to be hauled off-site.

Trash and Debris in the Inlet Level-Spreader

All trash and debris should be removed from the level-spreader on a regular basis. Depending on the characteristics of the drainage area to the facility, the level-spreader may need to be cleaned of accumulated trash and debris on a monthly basis.

Sedimentation of Inlet Level-Spreader

Once a significant portion of the level-spreader has filled-in (approximately 25-30% by volume), the level-spreader should be cleaned. Note: The North Carolina Department of Environment and Natural Resources, Division of Water Quality (919/733-7015) or Division of Waste Management/Hazardous Waste Services (919/508-8400), should be contacted regarding the proper testing and disposal of dredged material if it is to be hauled off-site.

Inlets

Inlets to the bioretention area should be kept open and in good working condition, and all eroded areas should be repaired.

Trash and Debris in Bioretention Area

All trash and debris should be removed from the bioretention area on a regular basis.

Erosion in the Bioretention Area

Any eroded areas should be repaired as soon as practicable.

Weeds in the Bioretention Area

Periodic weeding of the bioretention area may be necessary. The use of herbicides is not recommended.

Mulch Layer

Areas devoid of mulch should be remulched by hand. Every six months, in the spring and fall, a fresh layer of mulch should be added to the bioretention area. Every two to three years, in the spring, remove the old mulch before adding a new layer.

Sedimentation (or Clogging) of Bioretention Area

If the bioretention area is holding water for a period longer than 24 hours, the soil mix has, more than likely, become clogged with sediment and/or the underdrains have clogged. Typically, a bioretention area should not contain standing water for any longer than four to six hours after a rain event. Water may, however, pond for longer times during the winter and early spring. To correct a standing water problem, the following remedial actions are recommended:

1. Evaluate the drainage area to the bioretention area to identify any potential sources of sediment, such as an erosive condition, that may be contributing to the clogging of the device. If a source is identified, it is recommended that that source be eliminated to the fullest extent practicable before proceeding with the remaining recommendations provided below.

2. Flush the underdrains. If clean-outs for the underdrains have been provided, use them to flush the underdrains. Sediment in the drains may be preventing the soil mix from draining. Make sure to provide a way to capture any flushed sediment before it enters the stream environment or storm drain system downstream of the device. If, after flushing the underdrains, the device continues to hold water, the soil mix may be contaminated. As such, following the guidelines provided below is recommended.
3. Gage the extent of soil contamination. To do this, it is recommended that one or more test pits be dug with a shovel and that the soil layer be evaluated for contamination. Once the levels of contamination have been determined (for example, the top 4" of soil appears to be contaminated), it is recommended that you proceed with the remaining remedial actions.
4. Harvest the plants. Care should be taken in the removal and temporary storage of the plants so that as many as possible can be harvested for replanting in the bioretention area once the functioning of the device has been restored sufficiently.
5. Remove the mulch layer.
6. Remove the top few inches of contaminated soil plus an additional 2-inches of soil, and replace the removed soil with a clean soil mix in accordance with the soil mix specification applicable to the particular bioretention area.
7. Monitor the functioning of the bioretention area during the next two to three rain events. If the device appears to be draining as intended (e.g., there is no standing water four to six hours following a rain event), proceed with the remaining remedial actions. If the area continues to hold standing water, then the entire bioretention area soil mix and the underdrains may need to be removed and replaced. Especially, if the device continues to hold water for more than one to two days following a rain event. Reuse of any undamaged underdrains may be possible once they have been cleaned thoroughly.
8. Replant the harvested plants, and replace any plants that were rendered unusable during or following their removal from the bioretention area.
9. Replace the removed mulch layer with fresh mulch.
10. Water the plants in the bioretention for the next two or more weeks unless there is sufficient rainfall. This will help the plants to reestablish themselves.

Overgrown Vegetation

Sometimes, following several years of growth in a bioretention area, the vegetation will thicken to such an extent that sufficient sunlight is unable to reach the surface of the bioretention area. As this occurs, the bioretention area will begin to loose its ability to eliminate microbial bacteria. If a bioretention area is heavily overgrown, the vegetation should be thinned so that sunlight can penetrate the surface. As a side benefit, the removal of excess vegetation will promote greater public safety.

Damaged Concrete Impoundment Walls

Some bioretention areas are contained in concrete impoundment walls. These walls should be inspected regularly for damage. Minor cracks and spalled areas should be repaired as soon as practicable. If more significant damage is apparent (i.e., one wall is beginning to lean or has settled significantly, etc.), consultation with a registered Professional Engineer is recommended.

Provision of Fall Protection Across Impoundment Walls

Depending on the location of the bioretention area, the installation of handrailing or fencing around the perimeter of the impoundment walls may be necessary to protect the general public from falling into the device. Gated access points should be provided so that maintenance personnel will be able to enter the facility and perform needed maintenance functions.

Mosquitoes

Since a bioretention area is **not** really a pond, per se, it, typically, will not provide a suitable habitat for the breeding of mosquitoes. However, when a bioretention area begins to hold standing water for more than four days, mosquitoes may begin to breed in the device. For a discussion of mosquito issues, please refer to **Section 1: Stormwater Ponds**.

Outfall Area Maintenance

Blockages

A blocked outfall channel should be opened up as soon as practicable, especially if the channel is backing a significant amount of water up inside the PSP. Typically, outfall channels should be cleared of trees for a distance, downstream from the outfall structure, of at least 5 times the diameter of the PSP. For example, the clearing area for a 36" (three-foot) diameter PSP would be 15-feet long. Note: Established vegetation and trees on the stream banks should be left in place. The "clearing" should be limited to the removal of dead and fallen trees and anything in the flow-line of the channel that significantly prevents water from exiting the bioretention area.

By-Pass/Diversion Structure Maintenance

Blockages

All trash, sediment, and debris blocking the entry or passage of storm flows through the structure should be removed.

SECTION 6

WATER QUALITY SWALES

FUNCTIONAL ELEMENTS

Definition of Device Type

Water Quality (aka Grassed) Swale: A water quality (WQ) swale is a shallow open-channel drainage way stabilized with grass or other herbaceous vegetation designed to slow stormwater runoff and to filter pollutants. WQ swales can filter out pollutants as stormwater runoff moves through the leaves and roots of the grass. By reducing flow velocities and increasing a site's time of concentration, these swales can contribute to a reduction in peak runoff rates. Swales that are designed with check dams or that incorporate depression storage can promote infiltration. Broad swales on flat slopes with dense vegetation are the most effective at pollution removal. It should also be noted that removal efficiencies are highest for sediment bound pollutants (i.e., TSS, phosphorous, etc.).

Glossary of Primary Elements

Check Dam: A small dam (e.g., 3- to 6-inches tall), constructed of earth, stone, timber, or a combination thereof, intended to retain a small portion of runoff from small, frequent rain events. A weep hole may be added to enable ponded water behind an earthen or timber dam to drain off when infiltration rates are low. Such weep holes will, though be subject to frequent clogging. Shorter check dams can serve a level-spreader-like function by "correcting" the channel and redistributing flow along the swale's cross-section.

Depression Storage: Small depressions along the bottom of a water quality swale can trap and store stormwater and, as such, promote infiltration into the soil. These depression areas may accumulate sediment at a quicker rate than in other parts of the swale. In addition, these areas may also tend to develop wetland vegetation.

Lot Line Swale: This type of swale is usually located between houses and, typically, runs the length of a lot. Lot line swales receive runoff from downspout gutter discharges and from lot areas.

Primary Outlet Swale: This swale usually collects drainage from roadside swales and lot line swales, though they are sometimes located along lot lines. Because of the heavy hydraulic load, a primary outlet swale is usually deeper, wider, and longer than a roadside or lot line swale.

Roadside Swale: Roadside swales are usually found on both sides of a road, are typically interconnected with cross pipes, and empty into a primary outlet swale. A roadside swale often collects runoff from lot line swales and, as such, carries heavy hydraulic and pollutant loads.

Inlet: A pipe or open channel that discharges collected stormwater into a water quality swale.

Underdrain: A perforated drain pipe, which is sometimes placed beneath a flat swale to aid in the draining of the swale. The underdrains may be connected to a storm structure or daylighted into a downstream conveyance device, such as a roadside or primary outlet swale.

MAINTENANCE REQUIREMENTS

Erosion and Sediment Control Requirements

Please refer to **Section 2: Stormwater Ponds**.

Vegetative Maintenance

Turf Maintenance

When turf grass is the predominant vegetative cover, the grass should be allowed to grow to the maximum height consistent with the variety of grass present. When mowed, the grass should be cut to a height of no lower than approximately 6-inches. The primary purpose of any mowing activities is to retard the growth of woody vegetation and to keep the turf grass groomed in a manner that maintains optimal vegetative health. If turf reinforcing mat (TRM) is present, care should be exercised such that portions of the TRM do not get caught in the mower blade.

Wetland/Wet Meadow Vegetation Management

Swales populated with wetland or wet meadow vegetation do not require routine mowing. However, if the vegetation has become so dense that it is preventing the effective passage of flow through the swale, selective thinning (by hand) of the vegetation may be required. In addition, any woody vegetation present in the swale should also be removed (also by hand).

Bare Areas

The existing soil in all bare areas should be scarified and amended with topsoil, lime, and fertilizer prior to vegetative reseeding. Seed mixtures used in the reseeding should be consistent with the vegetation present throughout the main portion of the swale or swale system.

Eroded Areas

Eroded areas should be repaired as soon as practicable. Erosion in the bottom of a swale may be indicative of insufficient vegetative cover, higher than originally anticipated flow velocities, channel constrictions, or other irregularities in the construction of the channel. The cause/s of the erosive condition should be investigated and corrected prior to any reseeding operations.

Fertilization

Once fertilizer has been applied to establish the initial vegetative cover, additional fertilization efforts should not be required except as indicated above after repairing a bare or eroded area.

Trash and Sediment Removal

<u>Trash and Yard Waste Removal</u>

Any visible trash or yard debris should be removed from the swale as this material can block the swale, adversely affect the health of the swale's vegetation, as well as provide a potential mosquito breeding habitat.

<u>Sediment</u>

Accumulations of sediment that exceed a 4-inch depth should be removed. Special attention is directed to the area behind a check dam or in a depression storage area. Any disturbed areas should be scarified, amended, and reseeded as described above in **Vegetative Management**. The presence of sediment may be indicative or an erosive condition upstream. Measures to correct any instabilities in the upstream drainage area should be taken prior to performing any sediment removal operations.

Other Issues

<u>Standing/Ponding Water</u>

Ponding water in a WQ swale can be beneficial if the design and construction of the swale specifically accounted for such conditions. If ponding water was not an intended condition and is now being viewed negatively by surrounding residents, the swale could be modified in one or more of the following ways: (1) wetland vegetation could be planted in the areas where ponding water is frequently present; or (2) a turf grass cover could be established and maintained in these areas such that the swale could drain more completely; or (3) an underdrain system could be installed to alleviate the standing water by providing a means for the water to seep into the ground, enter the underdrain, and find passage away from the system. It should be noted that the implementation of suggested remedy (3) should be undertaken only after careful consideration of the costs involved and the availability of a means to daylight the underdrain.

<u>Mosquitoes</u>

For a discussion of mosquito issues, please refer to **Section 1: Stormwater Ponds**.

SECTION 7

LEVEL SPREADERS

FUNCTIONAL ELEMENTS

Definition of Device Type

Level Spreader: A level spreader is a device that consists of a forebay, storage channel, and a linear structure, usually made of concrete or timber, that is constructed at as close to a zero percent slope as possible. Depending on the use of the level spreader, other elements may include a high flow bypass system and a filter strip. One of the main purposes of a level spreader is to disperse concentrated stormwater flows over a wide enough area to prevent erosion of the BMP or filter strip into which the level spreader drains stormwater. It should be noted that the design of level spreaders has gone through significant evolution in the last few years. As such, there may be many level spreaders in the field that do not contain all the elements presented in this section. In addition, the structural configuration of some elements may very considerably from one device to another.

Glossary of Primary Elements

By-Pass Structure: A structure that forces high flows (e.g., flows greater than the 1"/hr event) to by-pass a level spreader all together. The intent of a by-pass structure is to reduce the potential for overwhelming (and, possibly, blowing out) the level spreader stormwater device. Typically, by-passed flows are directed into an outfall pipe that drains to a riprap lined stilling basin. The stilling basin should be sited such that it empties into a natural drainage channel.

Filter Strip: A section of land, either forested or vegetated (with turf grass or other plants), capable of sustaining a sheet flow regime as stormwater runoff flows across it.

Forebay: A depression (usually lined with rock) located where a pipe or swale enters a level spreader. It is intended to capture particulate pollutants, such as small stones, sand, and heavy sediment, by slowing the water velocity such that particulates are able to settle out in a relatively confined area.

Level Spreader Weir (or "Lip"): A linear structure, usually made from concrete or timber, that is constructed at as close to a zero percent slope as possible. The weir is the controlling device that produces a dispersed, sheet flow regime to the stormwater exiting the device. On the downstream side of the weir, a 3-ft wide by 3-in deep layer of crushed (e.g., #57) stone should be present.

Stilling Basin: A riprap lined depression intended to dissipate the energy of flows by-passing a level spreader device. A stilling basin should be sited such that it empties into a natural drainage channel.

Storage Channel: A channel, between the forebay and the level spreader weir, that "stills" stormwater prior to its discharge over the weir.

MAINTENANCE REQUIREMENTS

Erosion and Sediment Control Requirements

Please refer to **Section 2: Stormwater Ponds**.

Impoundment Area Maintenance

<u>Sedimentation of Forebay</u>

Once a significant portion of the forebay has filled-in (approximately 25-30% by volume), the forebay should be cleaned. Note: The North Carolina Department of Environment and Natural Resources, Division of Water Quality (919/733-7015) or Division of Waste Management/Hazardous Waste Services (919/508-8400), should be contacted regarding the proper testing and disposal of dredged material if it is to be hauled off-site.

<u>Level Spreader Weir</u>

The weir (and crushed stone layer) should be inspected for any settlement, deterioration, erosion, or channelized flow. Settled or deteriorated weirs may need to be replaced or modified. Modifications could include the installation of an adjustable plate to the downstream face of the weir.

<u>Mosquitoes</u>

For a discussion of mosquito issues, please refer to **Section 1: Stormwater Ponds**.

By-Pass Structure Maintenance

<u>Blockages</u>

All trash, sediment, and debris blocking the entry or passage of storm flows through the structure should be removed.

Outfall (from By-Pass Structure) Area Maintenance

<u>Blockages</u>

A blocked outfall channel should be opened up as soon as practicable, especially if the channel is backing a significant amount of water up inside the discharge pipe. Typically, outfall channels should be cleared of trees for a distance, downstream from the outfall structure, of at least 5 times the diameter of the PSP. For example, the clearing area for a 36" (three-foot) diameter pipe would be 15-feet long. Note: Established vegetation and trees on the stream banks should be left in place. The "clearing" should be limited to the removal of dead and fallen trees and anything in the flow-line of the channel that significantly prevents water from exiting the by-pass structure.

Structural Integrity

Depending on the severity of the deterioration, the bypass structure may need to be replaced. If the overall integrity of the structure is reasonably sound, the following repairs should be considered:

- Cracks should be sealed with an epoxy low-shrink grout.
- Spalled areas should be repaired with a two-part cement-bonding agent and then painted.
- Rusted areas, if reparable, should be scraped, cleaned, primed, painted with two coats of rust-resistant paint, and, if appropriate, coated with a bituminous sealant.

Filter Strip Maintenance

Please refer to **Section 8: Filter Strips**.

SECTION 8

FILTER STRIPS

FUNCTIONAL ELEMENTS

Definition of Device Type

Filter Strip: A filter strip is a section of land, either forested or vegetated (with turf grass or other plants), capable of sustaining a sheet flow regime as stormwater runoff flows across it. A filter strip can be quite effective at removing certain pollutants from stormwater.

Glossary of Primary Elements

Inlet Level-Spreader w/ Forebay: A device, immediately upstream of a filter strip, intended to remove heavy particulates from stormwater and then spread or disperse inletting flows into a sheet flow regime. A level spreader and forebay is typically required with every filter strip unless permanent, sustained sheet flow can be demonstrated otherwise.

MAINTENANCE REQUIREMENTS

Erosion and Sediment Control Requirements

Please refer to **Section 2: Stormwater Ponds**.

Vegetative Maintenance

Turf Maintenance

When turf grass is the predominant vegetative cover in the filter strip, the grass should be mowed two to three times a year, and the clippings should be harvested to promote the growth of thick vegetation. When mowed, the grass should be cut to a height of no lower than approximately 6-inches.

Bare Areas

The existing soil in all bare areas in the filter strip should be scarified and amended with topsoil, lime, and fertilizer prior to vegetative reseeding or replanting. Any plantings or seed mixtures to be used in the reseeding/replanting should be consistent with the vegetation present in the filter strip.

Eroded Areas

Eroded areas should be repaired as soon as practicable. Erosion in the filter strip may be indicative that concentrated flows are occurring in the filter strip. Concentrated flows may be the result of insufficient vegetative cover, higher than originally anticipated flow velocities (especially in wooded filter strips), and/or a malfunctioning level spreader device. The cause/s of the erosive condition should be investigated and corrected prior to any repair operations. Once the cause of the erosive condition have been corrected, the eroded areas should be repaired and revegetated in a manner similar to that covered in Bare Areas above.

Fertilization

Once fertilizer has been applied to establish the initial vegetative cover, additional fertilization efforts should not be required except as indicated above after repairing a bare or eroded area.

Level Spreader Maintenance

Please refer to **Section 7: Level Spreaders**.

Trash and Sediment Removal

Trash Removal

Any visible trash in the filter strip should be removed as this material can adversely affect the function of the filter strip.

Sediment

Accumulations of sediment that exceed a 4-inch depth should be removed. Any disturbed areas should be scarified, amended, and reseeded/replanted as described above in **Vegetative Management**. The presence of sediment may be indicative or an erosive condition upstream. Measures to correct any instabilities in the upstream drainage area should be taken prior to performing any sediment removal operations.